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Too Big To Fail: Limiting Public Risk in Hydropower Licensing

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The financial crisis of 2008 resulted in widespread economic distress and near collapse of the global financial sector. While the causes of the crisis were complex, the emerging corrective outcomes provide insight as to how large, interconnected institutions with direct oversight of high-valued resources should be regulated. In the case of the financial sector, improved regulatory oversight has resulted in a series of changes for banks that are deemed *too big to fail*. In other words, banks—whose financial assets and obligations are so valuable that their potential demise would have catastrophic and cascading impacts to other connected institutions and constituents in "downstream" transactions—are now required to limit their exposure to internal and external system shocks. In response to this crisis, methods to assess and reduce relative risk and exposure, as well as the development of preparedness and response strategies in the event of future adverse conditions, were generated via new fiscal and monetary policies. These policies have centered on four pragmatic reforms: stress testing, performance monitoring, triggers for remediation, and escrow accounts to maintain liquidity.[1]

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1. John Maxfield, *The Dodd-Frank Act Explained*, THE MOTLEY FOOL (Feb. 2, 2017, 2:39 PM), https://perma.cc/ZV9S-AQL7. (Ultimately these reforms, and others, were included in the Dodd–Frank Wall Street Reform and Consumer Protection Act.)

Large-scale water management systems in general, and California's water management system in particular, provide a good analogue to the financial system. In California, our water system meets the needs of more than 39 million people, supports the irrigated production of over a third of the nation's vegetables and two-thirds of the nation's fruits and nuts, and powers the fifth largest economy in the world.[2] However, it is also highly decentralized and routinely subject to system shocks, such as prolonged drought. In essence, our water management system is *too big to fail*. We argue here that similar policy reforms are necessary to reduce future system shocks in water management systems caused by global climate warming and subsequent alteration to regional hydroclimatic regimes, and thereby reduce exposure of downstream beneficiaries to unnecessary risk. While such reforms in the financial sector were reactionary, the case for proactive climate change adaptation in water management—and in hydropower relicensing specifically—has been made previously because the stakes are too high and the risks too great.[3]

These observations are especially important today as a recent spate of bills in the U.S. Congress have attempted to roll back regulation of water management activities, such as the most recent H.R. 23 Gaining Responsibility on Water Act of 2017.[4] Other bills have focused on deregulation of hydropower production in the United States.[5] These bills cite, among many things, the desire to expedite future dam and hydropower development.[6] In particular, the "improvements" sought by the latter bill are to lessen protection for the environment and limit scientific scrutiny by utilities regulated by the Federal Energy Regulatory Commission seeking to

2. *See* State of Cal. Dep't of Fin., E-1 POPULATION ESTIMATES FOR CITIES, COUNTIES AND THE STATE WITH ANNUAL PERCENT CHANGE (2016-2017), https://perma.cc/AGP5-3SQU; *see also* Cal. Dep't of Food and Agric., CALIFORNIA AGRICULTURAL PRODUCTION STATISTICS 2016 CROP YEAR REPORT (2016), https://perma.cc/44G7-YPL9 (California's share of global gross domestic product (GDP) varies from year to year, but is routinely in the top ten compared to other countries.).

3. Joshua A. Viers, *Hydropower Relicensing and Climate Change*, 47 J. OF AM. WATER RESOURCES ASS'N. 655, 655–661 (2011).

4. Richard Frank, *California Members of Congress Seek to Eviscerate State Water & Environmental Law*, LEGAL PLANET (July 10, 2017), https://perma.cc/9J43-NDER.

5. Hydropower Improvement Act, S.1236, 114th Cong. (2015); Energy Policy Modernization Act, S. 2012, 114th Cong. (2015).

6. Senator Lisa Murkowski & Jay Faison, *Stop Wasting America's Hydropower Potential*, N.Y. TIMES (Jan. 14, 2016), https://www.nytimes.com/2016/01/14/opinion/stop-wasting-americas-hydropower-potential.html.

extend hydropower operation licenses under the Federal Power Act (as amended).[7] We argue that hydropower—particularly in California, which depends on a large and complex network of hydropower facilities—would benefit from more robust regulation given anticipated shifts to the hydroclimatic regime due to global climate change.

Climate Change & Hydropower Relicensing

In the United States, the federal agency responsible for regulating the generation, transmission and sale of energy is the Federal Energy Regulatory Commission (FERC), which regulates the transportation of oil in interstate commerce, the transmission of natural gas, and licenses nonfederal hydropower projects. The stated mission of FERC is to "assist consumers in obtaining reliable, efficient and sustainable energy services at a reasonable cost through appropriate regulatory and market means."[8] Although largely unknown to most Americans, FERC has enormous sway in how hydropower generation is conducted, and ultimately who, if anyone, is responsible for its potential negative effects.

Hydropower is a renewable source of energy and represents approximately twenty percent of the world's energy supply.[9] As an energy source, it is viewed as both vulnerable to global climate warming[10] and an asset to reduce climate-altering emissions.[11] Hydropower is particularly vulnerable to hydrologic alteration driven by global climate warming[12] as its

7. Ben Adler, *Is Obama Blocking Smart Hydropower Development*?, GRIST (Jan. 27, 2016), https://perma.cc/8K37-94F6; *see also* Senator Lisa Murkowski & Jay Faison, *supra* note 6 (Pacific Gas & Electric Vice President Randal Livingston provided evidence to the Committee on Energy and Natural Resources. Livingston cited specific grievances that are remedied by limiting non-licensee data collection and limiting interpretation of project nexus determination, both of which would serve to limit scientific scrutiny of proposed actions).

8. Federal Energy Regulatory Commission, https://perma.cc/8X4B-WD48.

9. Cutler Cleveland, ENCYCLOPEDIA ENERGY, 325–332 (1st ed. 2004).

10. Bernhard Lehner et al., *The Impact of Global Change on the Hydropower Potential of Europe a Model-Based Analysis*, 33 ENERGY POLICY 839, 839—855 (2005).

11. Lea Kosnik, *The Potential of Water Power in the Fight Against Global Warming in the* U.S., 36 ENERGY POLICY 3252, 3252–3265 (2008).

12. Zbigniew W. Kundzewicz and Luis José Mata, CLIMATE CHANGE 2007: WORKING GROUP II: IMPACTS, ADAPTATION AND VULNERABILITY 211–272 (Alfred Becker et al. eds., 2007).

generation depends directly on the magnitude and timing of available "fuel," or stream discharge. Hydropower is also increasingly the focus of regulatory agencies trying to more effectively manage multiple ecosystem service benefits.[13] These issues are particularly topical in California, as the state grapples with a water supply that is increasingly stretched between numerous demands, including energy production, domestic, industrial and agricultural water uses, flood control, recreation, environmental conservation, and hydropower generation.[14]

Recently, climate change research has focused on the increasing frequency and documentation of extreme weather events, such as droughts, floods, and hurricanes. The vulnerability of California's water system to these types of climate shocks has been on stark display over the past several years. Following the prolonged 2012-2016 drought, which created the very real possibility that hydropower facilities would not be able to meet their electricity generation goals, California experienced what is, by most accounts, a record precipitation year.[15] As a result, catastrophic flooding occurred across the state, with enormous damage to property and infrastructure, the most visible of which was the spillway of the Oroville Dam.

Several environmental advocacy groups had previously identified design flaws in the Oroville Dam, the largest reservoir in California's State Water Project, which centered around the potential for downstream risks to public safety.[16] These concerns were largely dismissed by the California Department of Water Resources (DWR), the operator of Oroville Dam, and by FERC during the original licensing.[17] Interestingly, the Oroville Dam was slated for relicensing in 2007, but the process had been delayed for approximately ten years before an extreme atmospheric river event in 2017

13. Birgitta Malm Renöfält, *Effects of Hydropower Generation and Opportunities for Environmental Flow Management in Swedish Riverine Ecosystems*, 55 FRESHWATER BIOLOGY 49, 49–67 (2009).

14. Ellen Hanak et al., *Managing California's Water from Conflict to Reconciliation*, PUBLIC POLICY INSTITUTE OF CALIFORNIA, 2011, at 102.

15. Press Release, Northern Sierra Precipitation Sets Water Year Record, Cal. Dep't of Water Res. (Apr. 12, 2017).

16. Motion to Intervene of Friends of the River Sierra Club South Yuba Citizens League at 14-16, Project No. 2100-52 (Submitted before the end of the filing period to provide the Federal Energy Regulatory Commission staff and the licensee with an early presentation of the licensing issue.).

17. Sam Stanton & Ryan Sabalow, *State Water Officials Were Warned of Oroville Dam Weakness a Dozen Years Ago*, THE SACRAMENTO BEE (Feb. 13, 2017), https://perma.cc/Y3J7-RAJ4.

brought significant damage to the spillway structure.[18] Joined by others, these same stakeholders are currently challenging the FERC relicensing due to the unaddressed public safety concerns in addition to downstream environmental impacts.[19] As a result, Oroville Dam faces further relicensing delays in consideration of the safety of the facility and other factors[20] and presumably increased scrutiny in how this facility will handle future uncertainty in extreme climatic events.

Such scrutiny is important because FERC presently does not require consideration of climate altered or non-stationary hydrology in its issuance of hydropower operating licenses, which are issued for a period of thirty to fifty years. The current re-licensing process administered by FERC appears at odds with emerging best practices for climate change adaptation given recent observations of extreme climatic events and the concurrent move toward integrated water resources management and planning, which promotes the coordinated development and management of water resources to maximize social benefit while sustaining ecosystems.[21] In California, climate change adaptation strategies in integrated water resources management have included improved conjunctive use of groundwater through the Sustainable Groundwater Management Act of 2014[22] and development of multi-benefit setback levees to mitigate extreme flood events.[23] In general, however, the best practices advocated by DWR through its Climate Action Plan has not included specific recommendation for changes to hydropower operations to plan and mitigate for extreme events, such as flood and drought.[24]

18. Eric Holthaus, *The Dam Truth: Climate Change Means More Lake Orovilles*, Grist (Feb. 16, 2017), https://perma.cc/2QPY-9CAG.

19. Ryan Sabalow & Dale Kasler, *Groups Demand Transparency on Oroville Dam Spillway Repairs*, THE SACRAMENTO BEE (Apr. 19, 2017), https://perma.cc/EPZ8-7GC6.

20. Motion to Intervene of Friends of the River Sierra Club South Yuba Citizens League, *supra* note 18, at 14–16.

21. Jordi Gallego-Ayala, *Trends in Integrated Water Resources Management Research: A Literature Review*, 15 WATER POLICY 628, 628–647 (2013).

22. Sustainable Groundwater Management Act; A.B. 1739, 2014 Leg., Reg. Sess. (Cal. 2014); S.B. 1319, 2014 Leg., Reg. Sess. (Cal. 2014); S.B. 1168, 2014 Leg., Reg. Sees. (Cal. 2014).

23. Ellen Hanak & Jay Lund, *Adapting California's Water Management to Climate Change*, CLIMATIC CHANGE, 2011, at 102.

24. *See* PERSPECTIVES AND GUIDANCE FOR CLIMATE CHANGE ANALYSIS, Cal. Dep't of Water Res., 2015, https://perma.cc/5PBP-HHDY. (DWR recommends stress testing with extreme scenarios, e.g., outside of observed record).

Climate Change Adaptation in Water Resources Management

The water resources management sector has historically dealt with climate variability and uncertainty in strategic ways. This adaptation is most evident often during periods of floods or droughts when our water management infrastructure is used to ameliorate imbalances in supply and demand across space and time, where storing water for several years and delivering it over 1000 km away is routine. For California, the construction of numerous dams and aqueducts under the federal Central Valley Project and the State Water Project during the middle of the 20th century was an elaborate engineering approach to capturing and storing water from places of supply and delivering it to places of demand. This infrastructure is a form of longer-term adaptation to stationary climate signals,[25] which often rely on the assumption that observations from the historical record are sufficiently robust to capture the range and variability of any future event. However, non-stationary hydroclimatic trends challenge the underlying basis for static approaches to water resource management.[26] Recent non-stationary behavior in hydroclimatic signals—such as increased frequency and severity of droughts and decreasing trends in snowpack —have prompted the use of adaptive management, which uses a shorter-term set of measures that center on flexible operations, forecasting and innovative uses of existing delivery and supply infrastructure to meet unexpected demands and ameliorate hydroclimatic extremes.[27] Used correctly, adaptive management provides a framework for flexible decision-making in rapidly changing environments as results from management actions become available or as new information comes to light.[28] The concept of adaptive management has been discussed extensively for management of natural resources and water management generally, and for climate change adaptation in particular.[29]

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25. Eugene Z. Stakhiv, *Pragmatic Approaches for Water Management Under Climate Change Uncertainty*, 47 JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION 1183, 1186 (2011).

26. P.C.D. Milly et al., *Stationarity Is Dead: Whither Water Management?*, 319 SCIENCE 573–574, 573 (2008)

27. National Research Council, *Adaptive Management for Water Resources Project Planning*, THE NATIONAL ACADEMIES PRESS, (2004).

28. Kai N. Lee, *Appraising Adaptive Management*, *in* BIOLOGICAL DIVERSITY: BALANCING INTERESTS THROUGH ADAPTIVE COLLABORATIVE MANAGEMENT 1-26 (Louis E. Buck & Charles C. Geisler eds., 2001).

29. *Id.*; *see also* Claudia Pahl-Wostl, *Transitions Towards Adaptive Management of Water Facing Climate and Global Change*, 21 WATER RESOURCES MANAGEMENT 49, 49–62 (2007); *see also* Alejandro E. Camacho, *Adapting Governance to Climate Change: Managing Uncertainty Through a Learning*

As applied in the financial sector, this framework includes periodic "stress tests" and exercises to provide new information and response strategies.[30] Such stress tests quantitatively determine the reliability of management structures, robustness of contingency actions, and overall resilience of the study system.[31] In the case of hydropower relicensing under FERC, the formal development of study plans, which often include elements of hydrodynamic modeling, is the only equivalent to stress testing afforded by licensees to managing agencies and stakeholders.[32]

Remedies to Existing Relicensing

Climate change adaptation in the water resources sector is a formal or informal response to changing environmental conditions and can be infrastructure-based, e.g., reinforcing levees to buffer against floods of higher magnitude and frequency, or more programmatic, e.g., incentivizing flood protection measures via tax policy.[33] Formal incorporation of adaptive management in hydropower relicensing has been rare despite its apparent suitability for water resource management in an era of hydroclimatic change.[34] This is not to say that relicensing does not provide opportunity for improvement, as alterations to infrastructure and operations are routinely

Infrastructure, 59 EMORY L.J. 1, 1–77 (2009); Robin K. Craig, *"Stationarity is Dead" - Long Live Transformation: Five Principles for Climate Change Adaptation Law*. 34 HARV. ENVTL. L. REV. 9, 9–73 (2010).

30. John Crabb, PRIMER: *Dodd-Frank and Stress Testing*, INTERNATIONAL FINANCIAL LAW REVIEW, Sept. 22, 2017; *see also* Maxfield, *supra* note 1.

31. *Id.*

32. Here we draw a distinction between "stress testing" of FERC licensed facilities for response management to non-stationary hydroclimates, and the recent stress testing by the California Department of Water Resources to evaluate structural integrity of dams statewide following the Oroville Dam Spillway incident, as well as the stress testing by the State Water Resources Control Board to evaluate conservation mandates imposed on water agencies to ensure sufficient water to serve customers for several years, based on average demand during the just-concluded 2012-2015 drought period. The stress testing advocated within the California Climate Action Plan is more relevant. PERSPECTIVES AND GUIDANCE FOR CLIMATE CHANGE ANALYSIS, *supra* note 24, at 3, 42, and 55.

33. Mac Taylor, Managing Floods in California, LEGISLATIVE ANALYST REPORT (2017), https://perma.cc/NLN4-QPQG.

34. Michael Kiparsky, Anita Milman & Sebastian Vicuña, *Climate and Water: Knowledge of Impacts to Action on Adaption*, 37 ANNUAL REVIEW OF ENVIRONMENT AND RESOURCES 163, 163–194 (2012).

considered and implemented in relicensing under FERC's request or through settlement agreements.[35] These adjustments can include new investments in or rehabilitation of major infrastructure, as well as modifications to operations and maintenance that are not limited to incorporation of new regulations or altered operating conditions. However, these adjustments are often made only at the outset of each license issuance or renewal.[36] This policy approach provides some measure of surety to licensees from which to project future production and revenue for the life of the license.[37] The static nature and narrow view of this policy prescription prevents programmatic responses to conditions and events outside of previous experiences or in response to potential alternative conditions.

At least two assumptions underlie the counter arguments to formal inclusion climate change impact analysis as a standalone study plan. One, even if hydroclimatic change effects were a clear and pressing issue, it would be up to the licensee to effectively deal with its outcome. Two, if potential hydroclimatic changes were directly affecting valued resources, they would be mitigated for in the existing plant operations or in future relicensing efforts. With respect to the former assumption, it has been argued that leaving adaptation up to licensees risks failure without recourse, which is unacceptable if the water management system is indeed *too big to fail*.[38] With respect to the second assumption, evidence that mitigation is taking place is mixed, although there are instances where shortening license duration, aggregation of licenses, or more aggressive requests to reopen a license has been seen.

A. Shortening Licenses

One potential remedy to limit negative effects of non-stationarity on integrated water resources systems is to shorten the duration of hydropower licenses, as locking in management conditions for three to five decades is risky given mid-century hydroclimatic projections.[39] Longer, fixed license

35. *E.g.*, Colin Apse, John Banks, Laura R. Day, Jefferey J. Opperman & Joshua Royte, *The Penobscot River, Maine, USA: A Basin-Scale Approach to Balancing Power Generation and Ecosystem Restoration*, 16 ECOLOGY AND SOCIETY (2011).

36. While it is beyond the scope of this paper to explore all such instances, this review is provocative in this sense. *See* Michael A. Swiger, Ann P. Southwick & Stephanie L. Mairs, *Paying for the Change: Can the FERC Force Dam Decommissioning at Relicensing*, 17 ENERGY L.J. 163 (1996).

37. Viers, *supra* note 3, at 655–661.

38. *Id*.

39. Kiparsky, *supra* note 34, 163–194.

duration was intended to provide utilities with financial assurances via operational longevity.[40] Unfortunately, most early licenses were issued prior to the establishment of key environmental laws, such as the federal Endangered Species Act or Clean Water Act. Accordingly, the incorporation of such laws into modern relicensing efforts has increased the length of time for relicensure and thereby increased consulting costs, time, and resources expended by resource agencies, stakeholders, and FERC staff. FERC has revised its procedures in an effort to streamline processes, including its recommended Integrated Licensing Process (ILP), which incorporates *a priori* views of the various stakeholders along a strict timeline.[41] Given the current constraints of the ILP, there is little incentive for the licensee to embrace change from the status quo.[42] For example, it would be prudent to limit licenses to a time envelope within which climate change is unlikely to negatively impact hydropower generations, say thirty years.[43] If the current licensing period (thirty to fifty years) is deemed approriate to provide utilities the necessary surety for investment, some intervening reassessment should be made to determine if changes in hydroclimatic conditions have occurred that necessitate some reevaluation of operational conditions.[44]

B. Aggregation of Licenses

A second remedy to minimize the cumulative effect of hydropower operations on downstream beneficial uses and provide a means for action oriented climate change adaptation through coordinated reoperation is to aggregate or at least coordinate licenses within a single basin.[45] To a limited degree this already happens, but it is at the discretion of the licensees.[46] Given the complexity and cost of relicensing, there is a desire by licensees and stakeholders to stagger licenses to limit an overload of commitment

40. Lea-Rachel D. Kosnik, *Sources of Bureaucratic Delay: A Case Study of FERC Dam Relicensing*, 22 J.L. ECON. & ORG. 258, 262–263. (2006).

41. Apse, *supra* note 35 and Viers, *supra* note 3, at 655–661.

42 Kaveh Madani, *Hydropower licensing and climate change: Insights from cooperative game theory*. 34 ADVANCES IN WATER RESOURCES 174, 179–180 (Feb. 2011).

43. *Id.*

44. *See* Office of Energy Products Federal Energy Regulatory Commission, HYDROPOWER PRIMER: A HANDBOOK OF HYDROPOWER BASICS (2017); *see also* Sarah E. Null, David E. Rheinheimer & Joshua H. Viers, *Climate-Adaptive Water Year Typing for Instream Flow Requirements in California's Sierra Nevada*, 142 J. WATER RESOURCES PLAN. AND MGMT. 11 (NOV. 2016).

45. Kiparsky, *supra* note 34, at 163–194.

46. Kosnik, *supra* note 40 at 258–288.

and engagement. On the other hand, as most licenses are now issued with corresponding settlement agreements, there are increasing incentives to bundle various commitments into a single, comprehensive approach.[47] The exclusion of federal facilities from such approaches remains problematic.

C. Adaptive Licenses

While nearly all newly issued licenses include settlement agreements, a few are now including formal steering committees, such as the Ecological Resource Committees or ERCs that have been implemented in the Mokelumne and Feather River watersheds.[48] While the resulting recommendations to the licensee can provide an effective, non-litigious means to consider new information and adaptively alter operations, the ERCs are operated by consensus, which may be difficult to achieve given the many conflicting interests. Further, the licensee may have incentives to be uncooperative given potential additional expenses or revenue loss resulting from recommended actions.[49] That being said, some ERC members, such as federal land-owning agencies, have sufficient authority to enforce recommendations to the extent that they fall within the jurisdiction of that agency.

Needed Relicensing Reforms

While the existing relicensing process itself provides a basic mechanism for adaptation, the existing framework has yielded few substantive examples. During the relicensing period, numerous studies are conducted to assess the potential environmental impacts of operations. Formally incorporating climate change into the relicensing process is one way to address the points raised here and by others regarding climate change impacts on operations.[50] For example, climate change impacts studies could integrate assessments of updated knowledge about the hydroclimatic record and updated hydroclimatic projections into operations impact studies. Similar studies have been proposed to FERC, but rejected.[51] Therefore, formal incorporation of hydroclimatic change into FERC relicensing efforts will likely require reform of the process. Similar to

47. Apse, *supra* note 35.

48. *Id.*

49. *Id.* at 258–288.

50. D.E. Rheinheimer, S.M. Yarnell & J.H. Viers, *Hydropower Costs of Environmental Flows and Climate Warming in California's Upper Yuba River Watershed*, 29 RIVER RES. AND APPLICATIONS 1291, 1291–1305 (2013).

51. Viers, *supra* note 3, at 655–661.

banking institutions that are now considered *too big to fail* by regulatory authorities, reforms were made to the manner in which their financial worthiness was assessed.[52] Some of these institutional reforms have resonance with hydropower relicensing, including stress testing, performance monitoring, triggers for remediation, and escrow accounts.

A. Stress Testing

In the financial sector, large institutions with multiple and complex obligations and contingencies are now required to undergo "stress tests" to determine if system shocks, either from outside events or internal decision-making, will compromise the ability of the institution to meet its "downstream" obligations.[53] These tests are conducted to quantitatively determine the overall reliability of management structures, robustness of contingency actions given perturbation, and overall resilience of the institution.[54] Outcomes from these tests identify means by which to reduce relative risk and exposure to system shocks, and aid in the development of preparedness and response strategies in the event of future adverse conditions.[55]

Hydropower and water management institutions, with similarly complex obligations to downstream beneficial uses, should have comparable safety measures. In the case of hydropower relicensing under FERC, however, the development of study plans is the only equivalent to stress testing afforded by licensees to management agencies and stakeholders. And while these study plans do include quantitative approaches, including very detailed stream-reach flow studies and operations modeling, they have yet to formally incorporate hydroclimatic change.[56] Reforming this oversight through formal stress testing within a FERC relicensing purview could take many forms including: formal environmental impact studies, more academic sensitivity analyses, or

52. Maxfield, *supra* note 1.

53. Downstream is used here in both the figurative sense (i.e., cascading financial failures enabled by overleverage, such as the collapse of Bear Stearns) and literal sense as defined by the financial industry (i.e., consumers of financial products). *See* Anita K. Krug, *Downstream Securities Regulation*, 94 B.U. L. REV. 1589 (2014).

54. Maxfield, *supra* note 1.

55. *Id*.

56. Peter B. Moyle, Joseph D. Kiernan & John G. Williams, *Improving Environmental Flow Methods Used in California Federal Energy Regulatory Commission Relicensing*, HYDROPOWER REFORM COALITION (2011).

development of climate-informed worst-case scenario planning into existing study plans.

B. Performance Monitoring

Relicensing is a process that includes thorough stakeholder engagement, consultation with resource specialists, advice from well-staffed legal teams, etc., and one that is ostensibly intended to ensure that licensed operating conditions do not cause extraordinary harm to valued environmental or cultural resources.[57] Despite the extraordinary effort and money directed toward relicensing, the requirements for post-licensure performance monitoring are comparatively negligible. Stated differently, requirements for post-licensure environmental monitoring in hydropower licenses are commonplace, but are not used in an adaptive manner.[58] Study requirements are often short term and like other license conditions, the monitoring requirements must be supported by a clear nexus to operations.[59] Further, licenses typically do not specify any consequences based on the outcome of studies or monitoring, though the formation of ERCs could alleviate this limitation.

C. Triggers for Remediation

Performance monitoring is useful to the extent it exposes management strategies that fail to meet the objectives of integrated water resources systems. In the event that sub-optimal strategies are identified, remedial actions must be taken. Milestones or triggers need to be established so that during monitoring of system performance, managers can recommend remedial actions if objectives are not being met. In the case of California's water resources, the spillway and emergency spillway failures at Oroville Dam in 2017 are indicative of a triggering event requiring remediation, because by explicit intent FERC is responsible for implementing regulations, supervising inspections, and approving action plans intended to safeguard the public from catastrophic emergencies "defined in the regulations as an impending or actual sudden release of water at the project caused by natural disaster, accident, or failure of project works."[60] It is unclear, however, if substantive changes will be made to reservoir and hydropower operations following this event despite the desire of stakeholders to improve safeguards for public safety and limit degradation to the environment.

57. Viers, *supra* note 50.
58. *Id.*
59. Kosnik, *supra* note 40.
60. Viers, *supra* note 50.

D. Escrow Accounts to Maintain Liquidity

One of the chief lessons of the financial crisis is that systems that are *too big to fail* often imply private profit but, in the event of system failure, require public bailouts. In other words, the profit is private but the risk is public. This paradox can be seen in the hydropower context as the public largely depends on a group of large, complex, quasi-private entities to manage a necessary public good (i.e., water). A major remedial action following the financial sector meltdown is that financial institutions found to be overleveraged or insufficiently liquid via stress tests or performance monitoring are now required to maintain higher levels of capital to protect against system failure, and to limit cascading impacts on downstream dependents.[61] In the context of hydropower, an analogous recommendation would require hydropower operators to maintain escrow accounts with preset liquidity so that in the event of an emergency, the burden of remediation would be borne by the licensee rather than the public. This would not only enable rapid response in the event of an emergency, but could also finance adaptive management approaches to identifying, understanding, and remedying changing environmental conditions due to extreme hydroclimatic events. Further, these accounts could eventually be used in the event of project decommissioning to offset the large and largely publically financed costs of doing so.[62]

Conclusion

While in principle water resources management has evolved over time to reduce vulnerability and enhance system resiliency given high uncertainty of increased demands and diminished supplies, underlying assumptions have not. Despite mounting evidence to the contrary, assumptions of hydroclimatic stationarity remain.[63] Further, operational rules, such as those employed at Oroville Dam for flood control and reservoir releases, remain indexed to a previous hydrologic era. At the end of the day, licensees and

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61. Maxfield, *supra* note 1.

62. Dominique R. Scalia, *I'll Take the Benefits If You Pay the Costs: Weighing the Equities of Public and Private Funding Sources for Hydroelectric Dam Decommissioning*, 2 AM. INDIAN L.J. 2.

63. Stakhiv, *supra* note 29; *see also* R. J. Watts, B. D. Watts, J. J. Opperman & K. H. Bowmer, *Dam Reoperation in an Era of Climate Change*, 62 MARINE & FRESHWATER RES. 321, 321–327 (2011); Jamie Pittock & Joerg Hartmann, *Taking a Second Look: Climate Change, Periodic Re-Licensing and Better Management of Old Dams*, 62 MARINE & FRESHWATER RES. 312, 312–320 (2011).

stakeholders alike will only embrace anticipatory adaptation to the extent that scientific tools and underlying data can transcend institutional and regulatory barriers. While all relicensing parties have a need to embrace transparency and to seek license measures that are clear and enforceable, it is clear that socioeconomic and environmental values are different today than they were at the initial issuance of most FERC licenses. Further, the technological leaps being made today are beyond the imagination of anyone thirty to fifty years prior. Therefore, it is safe to assume that our knowledge and skill will only improve in the coming decades and that the remedies and reforms to relicensing presented here may be moot. However, until more comprehensive approaches such as integrated water resource management frameworks are more generally embraced, effective governance will remain elusive and institutional conflicts will prevail.[64]

64. Casey Brown, *The End of Reliability*, 136 J. WATER RESOURCES PLAN. AND MGMT. 143, 143–45 (2010).